8. ELECTRIC POWER SYSTEMS

8.2 <u>Offsite Power Systems</u>

8.2.2 Offsite Circuits within the AP1000 Scope of Design

In the second paragraph of Section 8.2.2 of the final safety evaluation report (FSER), the NRC staff stated that the main generator normally provides power to the main alternating current (ac) power system. When the main generator is not available, the generator output breaker is opened and the plant auxiliary power comes from the switchyard by back feeding through the main step-up transformers and the unit auxiliary transformers (UATs). There is also a maintenance source provided through a reserve auxiliary transformer (RAT). The maintenance source is site specific, and bus transfer to the maintenance source is manual. In Section 8.2.3.4, "Specific Interface Requirements for Supporting Chapter 15 Analyses," of the FSER, the U.S. Nuclear Regulatory Commission (the NRC or staff) stated that the AP1000 design uses no automatic transfers of reactor coolant pump (RCP) buses to alternate power supply. In addition, in Section 8.3.1, "Onsite Power Systems," of the FSER, the NRC stated that the 6.9 kilovolt (kV) buses are provided with access to the maintenance source through normally open circuit breakers connecting the bus to the RAT and that bus transfer to the maintenance source is manual.

In Technical Report (TR) (TR-79) "Electrical System Design Changes," Revision 1, the applicant added a fast bus transfer scheme, along with an operator-initiated maintenance transfer, to the AP1000 design. This change required installation of an additional RAT to allow complete bus transfer from UATs to RATs.

As a result of the above changes to Tier 2, the corresponding portions of the Tier 1 AP1000 DCD Table 2.6.1-3 (untitled) and Figure 2.6.1-1, "Main ac Power System," were affected.

8.2.2.1 <u>Evaluation</u>

The proposed change will allow transfer of 6.9 kV RCP buses from the UATs to the RATs. The applicant stated that the addition of the bus transfer scheme will avoid a reactor trip resulting from component failure or spurious actuation of the protective relaying associated with any of the main step-up transformers, UATs, or isophase bus duct, which would cause an RCP trip and a reactor trip. Thus, when either normal or preferred power supply is unavailable because of an electrical fault at either main step-up transformer, UAT, isophase bus duct, or nonsegregated bus duct, fast bus transfer will be initiated to transfer the loads to the RATs. In addition to the above, the applicant has also added operator-initiated, sync-supervised, closed-transition transfers on a bus-by-bus basis to the AP1000 design.

The NRC staff was concerned about a statement in Section 8.3.1.1.1 of the DCD, which reads:

> …in the event of a loss of voltage on these buses, the diesel generators are automatically started and connected to the respective buses and in the event of a fast bus transfer, the diesel generator connection to the bus is delayed such that the fast bus transfer is allowed to initiate.

This statement implies that the diesel generator is already running during the fast bus transfer and its connection to the bus is delayed. In Request for Additional Information (RAI) RAI-

SRP8.3.1-EEB-02, the NRC requested the applicant to clarify when the diesel generator would start during fast bus transfer. In a response dated July 11, 2008, the applicant revised Section 8.3.1.1.1 of the DCD to clarify the statement as follows:

> In the event where a fast bus transfer initiates but fails to complete, the diesel generator will start on an undervoltage signal, but if a successful residual voltage transfer occurs, the diesel generator will not be connected to the bus, as the successful residual voltage transfer will provide power to the bus prior to the diesel connection time of 2 minutes.

The NRC staff concluded that this revision to the DCD satisfies the staff's concern, and it finds this issue can be resolved subject to verification that the AP1000 DCD has been updated to include the revised paragraph. This was identified as Confirmatory Item (CI) CI-SRP8.3.1-EEB-02.

Subsequently in Revision 17, the applicant revised Section 8.3.1.1.1 of the DCD to include the above cited paragraph. On this basis, the NRC staff finds CI-SRP8.3.1-EEB-02 resolved.

8.2.2.2 Conclusion

The NRC staff has reviewed these changes and concludes that the additions of a RAT and the bus transfer scheme to the AP1000 design provide additional plant availability and enhance the offsite power supply to the safety-related battery chargers, RCPs, and those priority loads provided for defense-in-depth functions.

8.3 Onsite Power System

8.3.1 AC Onsite Power System

8.3.1.1 Electric Circuit Protection

In this section of the FSER, the NRC discussed the ratings and major types of protection systems employed for the AP1000 medium voltage switchgear. In TR-79, "Electrical System Design Changes," Revision 1, September 2007, the applicant made the changes described in the subsections below.

8.3.1.1.1 Rating of 6.9-kV Switchgear Buses

In TR-79, the applicant proposed to revise the short-circuit rating of 6.9-kV switchgear buses from the current 500 megavolt amps (MVA) (40 kilo-amperes (kA)) to 63 kA. The Tier 2 portions of the AP1000 DCD affected in the electrical area include Figure 8.3.1-1, "Post 72 Hour Tempory Electric Power One Line Diagram," and Table 8.3.1-3, "Component Data – Main Power System."

8.3.1.1.1.1 Evaluation

Originally, the DCD included the short-circuit rating of the 6.9-kV switchgear buses as 500 MVA (approximately 40 kA). The applicant proposed to revise the short-circuit rating from the current 40 kA to 63 kA. The applicant stated that the value change from 40 kA to 63 kA is based on revised short-circuit calculations that demonstrate that 63 kA is bounding, given the UAT/RAT size and the expected largest motor size driving the allowed impedance of the UAT/RAT transformers. In RAI-SRP8.3-EEB-01, the NRC staff asked the applicant to justify this change in terms of the reason the interrupting rating changed from 40 kA to 63 kA and whether the proposed change affects the onsite distribution system analysis.

In a response dated October 17, 2008, the applicant stated that the onsite distribution system analysis supports the described engineering values. The value change from 40 kA to 63 kA is based on a computation of short-circuit current from an infinite source upstream of a UAT/RAT, neglecting the minimal contribution between the X-Y secondary windings of the transformer. In addition, the applicant considered a conservative assumption of a 100-percent motor load on a 100-percent loaded transformer winding using a 6.5 multiplier for motor short-circuit contribution. This value was computed while establishing a transformer impedance low enough to allow for starting the single largest motor. This computation demonstrates that 40 kA is inadequate and that 63 kA is bounding given the UAT/RAT size and the expected largest motor size driving the allowed impedance of the UATs/RATs. The applicant stated that it will confirm these values with final design calculations.

8.3.1.1.1.2 Conclusion

The NRC has reviewed this change and concludes that the proposed rating of 63 kA is acceptable because, in the current design, the starting current value of the largest motor is 58 kA, which is well in excess of 43 kA for the 6.9-kV switchgear bus rating. Therefore, a 63-kA rating for the 6.9-kV switchgear bus bounds the largest motor. Based on this discussion, the NRC staff finds this issue resolved.

8.3.1.1.2 Air Cooled Chillers

In TR-79, the applicant proposed to revise DCD Figure 8.3.1-1 to show the air-cooled chillers VWS-MS-02 and VWS-MS-03 being fed from the 6.9-kV buses ES-1 and ES-2, respectively.

The Tier 2 portions of the AP1000 DCD affected include Figure 8.3.1-1.

8.3.1.1.2.1 Evaluation

Figure 8.3.1-1 of the DCD did not show the air-cooled chillers VWS-MS-02 and VWS-MS-03 being fed from the 6.9-kV buses ES-1 and ES-2, respectively. These loads were previously connected at the 480-volt (V) level. The applicant revised the DCD to reflect the connection of these loads directly to the 6.9-kV buses.

8.3.1.1.2.2 Conclusion

The NRC staff has reviewed this change and concludes that these loads were erroneously shown connected at the 480-V level and that the connection of the air chillers to the 6.9-kV buses is consistent with the design for this size of motor load. Therefore, the proposed change is acceptable.

8.3.1.1.3 Raw Water Feeder Breaker Change

In TR-79, the applicant proposed to revise DCD Figure 8.3.1-1 to show the three raw water pumps and their auxiliaries. The Tier 2 portions of the AP1000 DCD affected include Figure 8.3.1-1.

8.3.1.1.3.1 Evaluation

DCD Figure 8.3.1-1 in Revision 15 showed that three feeders for three raw water pumps were fed directly from 6.9-kV buses and their auxiliaries were powered from 480-V buses. The applicant has proposed to have each of these three feeders support the respective raw water pump and the associated auxiliaries of that pump. The proposed change allows a single feeder to the raw water pump house and distributes power within that structure.

8.3.1.1.3.2 Conclusion

The NRC staff has reviewed this change and concludes that it has no impact on the safety systems; therefore, it is acceptable.

8.3.1.2 Standby Diesel Generators

Section 8.3.1.2 “Standby Diesel Generators” contains the staff review of generator exciter and voltage regulator systems as well as power sources.

8.3.1.2.1 Generator Exciter and Voltage Regulator Systems

In the sixth paragraph of Section 8.3.1.2 of the FSER, the NRC staff stated that the generator exciter and voltage regulator systems are capable of providing full voltage control during operating conditions, including postulated fault conditions.

In TR-79, the applicant proposed to delete the word “static” from the description of the exciter type so that a more readily available design may be used.

In addition, the applicant revised the nominal power ratings of various pieces of equipment and diesel generator loading in Table 8.3.1-2, “Onsite Standby Diesel Generator ZOS MG 02B Nominal Loads,” of the DCD.

8.3.1.2.1.1 Evaluation

There are no regulatory criteria that require a specific diesel generator exciter type. Revision 15 of the DCD specified that each onsite diesel generator has a “static” exciter. The NRC staff’s FSER did not identify what type of exciter was used for standby diesel generators. The staff concludes that deleting the word “static” from the description of the exciter type will provide applicant flexibility in choosing what equipment is to be procured and there is no impact on performance requirements.

In Revisions 16 and 17 of the DCD, the applicant revised the rating and operating load sizes of various pieces of equipment and updated the affected diesel loading tables. The NRC staff reviewed the revised loads in Tables 8.3.1-1 and 2 and found that the total loads exceed the rating of diesel generators. The portions of the AP1000 DCD affected include Tables 8.3.1-1 and 2. In RAI-SRP8.3.1-EEB-01, the NRC staff noted that the sum of the total loads (automatic and manual) listed in each revised table exceeds the continuous rating of each diesel generator and requested the applicant to justify why it is acceptable to exceed the continuous rating of the diesel generator at this stage of the design. Also, the applicant was requested to describe provisions included in the design that will prevent overloading of the diesel generators when manual loads are powered from the diesel generator.

In a response dated June 23, 2009, the applicant stated that onsite standby diesel generators have a nominal rating of 4000 kW; however, the units will accept loads up to the overload ratings of the diesel generators for the period of time specified for those ratings. The intent of the diesel generator loading is to accept all automatic loads followed by other loads to be manually added under operator control. In addition, the applicant stated that the abnormal operating procedures include diesel generator load management details to be followed after the automatic load sequencing. These procedures will identify that additional loads can be manually loaded at the operator's option. The operator will assess plant conditions and available diesel generator capacity to determine if these additional components should be started. The operator has main control room indication of the current power demand on each of the diesel generators upon which to base his decision. The NRC staff finds the response to the RAI to be acceptable.

8.3.1.2.1.2 Conclusion

The NRC staff concludes that removing the word "static" from the type of exciter will provide the applicant more flexibility in choosing other excitation systems; therefore, the proposed change is acceptable. The staff also finds the changes made to Tables 8.3.1-1 and 2 for auto-connected loads to be acceptable because 1) the total auto-connected loads (2706 kW, 3126 kW) on each diesel generator is still within the continuous rating of 4000 kW, and 2) and the procedures that will prevent overloading of the diesel generators when manual loads are powered from the diesel generator are included.

8.3.1.2.2 Power Sources

In the third paragraph of Section 8.3.1.2 "Standby Diesel Generators" of the FSER, the NRC staff stated that during plant startup, shutdown, and maintenance, the generator breaker is opened. Under this condition, the preferred power supply system provides the main ac power from the high-voltage switchyard through the main step-up transformers and two UATs. Each UAT supplies power to about 50 percent of the plant loads. The UATs have two identically rated 6.9 kV secondary windings.

In TR-114 "AP1000 Auxiliary Building Boiler Sizing and Design," the applicant added a third two-winding UAT sized to accommodate the electric auxiliary steam boiler and site-specific loads. In addition, in TR-134 "AP1000 DCD Impacts to Support COLA Standardization" Revision 5, the applicant revised Subsection 8.3.1.1.1, "Onsite AC Power System," to describe the neutral overcurrent protection for the RATs.

As a result of the above changes to Tier 2, the portions of the Tier 1 AP1000 DCD affected include Figure 2.6.1-1*,* "Main AC Power System," and Tables 2.6.1-3 and 2.6.1-5.

8.3.1.2.2.1 Evaluation

The applicant has proposed a design change from a diesel-fired auxiliary steam boiler to an electric auxiliary steam boiler for the AP1000 to alleviate issues in current plants related to operational problems caused by fuel fouling in diesel-fired boilers in standby service. This change reduces the size requirement on the auxiliary boiler by over 50 percent (from approximately 70 megawatts (MW) to 25 MW). As a result, the applicant has added a third two-winding UAT sized to accommodate the electric boiler and site-specific loads. The third UAT would be located outside the turbine building in the transformer area. A 25-MW electric boiler would be installed in the boiler room of the turbine building along with its associated switchgear ES7, load center, and motor control center. This design change would not have any impact on the safety systems.

The NRC staff was concerned that the applicant did not provide any neutral overcurrent protection for the RATs. In RAI-SRP8.2-EEB-03 dated March 13, 2008, the NRC staff asked the applicant to justify its failure to provide neutral overcurrent protection for the RATs. In a response dated April 22, 2008, the applicant stated that it had inadvertently omitted the neutral overcurrent protection from page 8.3-2 of the DCD. The applicant committed to modify DCD Section 8.3.1.1.1 to show neutral overcurrent protection for the RATs. The staff finds the above design to be consistent with the recommendations of IEEE Standard 666, "IEEE Design Guide for Electric Power Service Systems for Generating Systems." This modification is CI-SRP8.2-EEB-03.

Subsequently in Revision 17 of the DCD, the applicant revised Section 8.3.1.1.1 of the DCD to include the neutral overcurrent protection for the RATs. On this basis, the NRC staff finds CI-SRP8.2-EEB-03 resolved.

8.3.1.2.2.2 Conclusion

The NRC staff has reviewed this change and concludes that the addition of the third UAT and its associated switchgear ES7 has no impact on the safety systems and, therefore, the proposed change is acceptable. In addition, the NRC staff finds the inclusion of the overcurrent protection for the RATs to be consistent with expected engineering practice and acceptable.

8.3.1.3 <u>Ancillary AC Diesel Generators</u>

In the first paragraph of Section 8.3.1.2 of the FSER, the NRC staff stated that the applicant has included two ancillary diesel generators located in the annex building to provide power to meet the post-72-hour power requirements following an extended loss of offsite power sources. Each ancillary diesel generator output is connected to a distribution panel.

In TR-79, the applicant proposed to revise Figure 8.3.1-3 of DCD Tier 2 to reflect a four-wire 100 A distribution panel from a three-wire 50 A distribution panel, and a 100 A breaker for both the diesel generator to the bus and for the test load tie to the bus from the 50 A breaker.

8.3.1.3.1 Evaluation

There are no regulatory requirements concerning the number or rating of wires to or from a non-safety related auxiliary diesel generator. The staff reviewed this change to see that it was a prudent change. Currently, DCD Figure 8.3.1-3 shows the size of the ancillary diesel generator distribution panels as 50 A with an incoming breaker of 30 A from the generator. The applicant proposed to revise Figure 8.3.1-3 of the DCD to reflect a four-wire 100 A distribution panel from a three-wire 50 A distribution panel, and a 100 A breaker for both the diesel generator to the bus and for the test load tie to the bus from the 50 A breaker. The applicant stated that since the full load current of the generator is 53 A, the main breaker of the distribution panel should be sized at the full capacity of the generator at a minimum. The diesel generator test load will also be changed to 100 A to allow for this generator to be tested at full capacity. The applicant made its selection based on the 480 volts alternating current (Vac) standard-sized distribution panels available in the industry. In addition, to facilitate the use of this source as a feed to 277 Vac lighting circuits, these panels would be changed from three-wire system to four-wire system.

8.3.1.3.2 Conclusion

The NRC staff has reviewed these changes and concludes that the original rating of the bus and breakers of the panel was undersized and that the proposed revised rating of the diesel generator distribution panel is adequate because it exceeds the full load current of the diesel generator. Therefore, the proposed change is acceptable.

8.3.2.1.1 Class 1E dc Distribution

In Section 8.3.2.1.1 of the FSER, the NRC staff stated that the Class 1E dc power system consists of four independent 125 V Class 1E dc safety system divisions (Divisions A, B, C, and D). Divisions A and D are each comprised of one battery bank, one switchboard, and one battery charger. Divisions B and C are each comprised of two battery banks, two switchboards, and two battery chargers; however, in Revision 17 of the DCD, the applicant changed the system voltage for the operation of Class 1E dc loads from 125 Vdc to 250 Vdc.

The portions of the AP1000 DCD affected include pages 8.1-2, 8.1-3, 8.3-10, 8.3-14 through 17, 8.3-22 through 26, and Table 8.3.2-1 through 7. The portions of the Tier 1 AP1000 DCD affected include Section 2.6.3 “Class 1E dc and Uninterruptable Power Supply System,” Table 2.6.3-1 (untitled), Table 2.6.3-3, “Inspections, Tests, Analyses and Acceptance Criteria,” and Table 2.6.3-4 (untitled).

As part of the NRC staff’s review of the proposed changes to the Class 1E dc system, the staff issued several RAIs. The NRC staff’s evaluation of the applicant’s responses to the RAIs is as follows:

8.3.2.1.1.1 Evaluation

In RAI-SRP8.3.2-EEB-01, the NRC staff requested the applicant to provide a discussion as to how this voltage change would impact motors, cables, protective devices, switchboard, and other equipment as applicable. Also, the applicant was asked to describe how motor sizing, cable sizing would still be compatible with valve loads.

In the response dated May 7, 2009, the applicant stated that dc motor-operated valve motors would draw less current to accomplish the required power. Cables sizes would be reduced considerably. As the current drawn by the same size (kw) motor is halved and the total voltage drop allowed is doubled, the cable sizes would be reduced accordingly. Electrical distribution equipment would require, nominally, one half the current rating. The staff agrees with the applicant that by increasing the system voltage the current would be reduced, the cable sizes would be reduced, and the electrical distribution equipment would require less current. Therefore, the NRC staff finds applicant’s response to be acceptable and finds this issue resolved.

In RAI-SRP8.3.2-EEB-02, the NRC staff noted that DCD Section 8.3.2.1 indicates that the operating voltage range of the Class 1E batteries is 210 to 280 Vdc and the maximum equalizing charge voltage for the Class 1E batteries is 280 Vdc. The applicant was asked to confirm that the connected dc equipment is designed to operate up to the maximum voltage 280 Vdc.

In a response dated May 7, 2009, the applicant stated that all connected equipment design specifications would include the new voltage limit requirements. Based on the above, the NRC staff finds that since specification of each piece of equipment will include the revised voltage specification, the applicant's response is acceptable and this issue is resolved.

In RAI-SRP8.3.2-EEB-03, the NRC staff requested that the applicant provide the load profiles (duty cycle) from one minute to 24/72 hours for each of the 24-hour and the 72-hour Class 1E 250 Vdc batteries. The applicant was asked to discuss battery margins (aging margin, design margin, temperature correction factor, margin associated with float current for 100 percent state of charge) and the expected service life of these batteries.

In a response dated June 23, 2009, the applicant stated that for battery aging margin a factor of 25 percent would be used for a 20 year qualified battery. Temperature correction would be based on minimum temperature of 60 degrees Fahrenheit. With regard to float current margin, the applicant stated that this margin is described as a consideration for quick turnaround to service after discharge. Since the electrical design described in AP1000 DCD utilizes a spare battery that can replace any safety related battery, there is no immediate need to replace the discharged battery. The replacement interval/service life of the batteries will be in accordance with the testing program replacement requirements. Replacement intervals will be based on degraded performance in accordance with the required test program. However, the applicant did not provide the load profiles for 24-hour and 72-hour batteries as requested by the staff. The staff indentified this as OI-SRP8.3.2-EEB-03 in the SER with Open Items.

Subsequently, in a letter dated May 10, 2010, the applicant stated that the nominal loads on the batteries are identified in DCD Tables 8.3.2-1, 2, 3, and 4 and that the design is based on intelligent assumptions on the loads. Also, as part of the response to the above OI, the applicant provided document APP-IDS-EOC-001, Revision 0, "Class 1E 250 V DC Battery Sizing, Charger Sizing and Available Short Circuit Current," for staff review at its Rockville, Maryland office to assess the adequacy of the 24-hour and 72-hour batteries. The staff reviewed the load profiles for loss of offsite power and loss-of-coolant accident from one minute to 24/72 hours for each of the 24-hour and the 72-hour Class 1E 250 Vdc batteries contained in this report. Based on its review, the staff concluded that since the AP1000 Class 1E 250 Vdc batteries are sized in accordance with the recommendations of IEEE Standard 485, "IEEE recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications," (which provides methods for defining the dc load and for sizing a battery to supply that load for stationary batteries), there is reasonable assurance that the batteries would be designed to have adequate capacity to meet their respective load profile. In addition, the staff determined that the battery qualification program and the applicable surveillance requirements per plant technical specification would ensure that the batteries would envelop their designed load profiles throughout their designed life. On this basis, the staff considers OI-SRP8.3.2-EEB-03 to be resolved.

In RAI-SRP8.3.2-EEB-04, the NRC staff requested that the applicant describe how the 24-hour and the 72-hour 250 Vdc batteries would be qualified for service life: If safety-related batteries would be qualified using the recommendations of IEEE Standard 535, "Standard for Qualification of Class 1 E Lead Storage Batteries for Nuclear Power Generating Stations," it is not clear how the standard applies since the standard was written under the assumption of an 8-hour duty cycle. Since AP1000 design duty cycles are significantly longer than 8-hour duty cycle and IEEE Standard 535 does not apply to duty cycles longer than 8 hours, the applicant was asked to describe how these batteries would be qualified for extended duty cycles of 24 hours and 72 hours the applicant . The applicant was also asked to discuss the failure mode(s) for both the 24-hour and 72-hour duty cycle batteries.

In a response dated May 7, 2009, the applicant stated that it intends to qualify the AP1000 safety-related batteries for 24-hour and 72-hour duty cycles through the implementation of industry standards IEEE standard 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations"; IEEE Standard 344-1987, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"; and IEEE Standard 535-1986 as they apply to the equipment.

The qualification process for the AP1000 24-hour and 72-hour duty cycle batteries would be outlined in a test plan. Qualification of the batteries would be accomplished by type testing of both duty cycle designs to the AP1000 service conditions associated with their projected service life. In the qualification process, the batteries would be subjected to aging (thermal, wear/operational), abnormal environmental and seismic conditions. There are no radiation and normal vibration conditions associated with the mounting locations of the batteries. Aging under normal and abnormal service conditions would be performed to degrade batteries to their end-of-life such that the safety function after the design basis event (seismic) would be verified.

The aging conditions would include both electrical (chemical) cycling and thermal accelerated aging. Electrical (chemical) cycling would be performed in compliance with IEEE Standard 323. The proposed electrical (chemical) cycling is in line with Section 8.2.2 (6) of IEEE Standard 535-1986 for cases when the service conditions are more severe than those specified within the standard. The electrical (chemical) cycling of the batteries is based on the AP1000 maintenance/surveillance requirements with no less than 10 percent margin. During the testing process the service and performance tests would be performed in conjunction with the thermal accelerated aging test of the batteries to place the batteries in an end-of-life condition. Upon completion of the battery aging, abnormal environmental testing to the AP1000 mild environment abnormal conditions would be performed. Following the abnormal environmental testing, seismic testing and a hard rock high frequency screening test would be performed.

At the completion of seismic testing, a post-seismic battery service test would be performed. The service test is used to demonstrate equipment functionality during and after the design basis event (seismic) which is a requirement per IEEE Standard 344 and IEEE Standard 323. This is different from IEEE Standard 535, which only requires a performance test to be performed. In the process of performing the qualification testing of the AP1000 batteries, the program would identify any failure mechanisms that may surface during the projected service life in an AP1000 plant.

In a conference call of May 21, 2009, the NRC staff requested that the applicant provide its step-by-step, detailed qualification test plan showing testing for desired qualified life of the batteries. However, the applicant did not provide its qualification test plan for the batteries prior to issuance of the SER with Open Items. This issue was tracked as OI-SRP8.3.2-EEB-04 in the SER with OIs.

Subsequently, in a letter dated March 2, 2010, as part of the response to the above OI, the applicant provided document EQ-TP-59-APP (APP-DB01-VPH-001), Revision 0, "AP1000 Test Plan for Safety Related 250 Vdc Batteries," for staff review at its Rockville, Maryland office. The staff reviewed the applicant's on-site documentation supporting the qualification methodology for the 24-hour and 72-hour extended duty cycle batteries. The applicant provided detailed steps that would be followed to qualify the batteries as requested by the staff. The qualification would be based on the requirements of IEEE Standard 323-1974, IEEE Standard 344-1987, and IEEE Standard 535-1986. Qualification of the Class 1E batteries would be performed by testing. Due to the difference in duty cycle, the test sequence would be performed on two groups of test cells. One group would be cycled and tested to the 24-hour duty cycle for AP1000 and the other group would be cycled and tested to the 72-hour duty cycle for AP1000. The test plan includes a series of modified performance tests at two year intervals that envelop the load profile of a service test throughout the installed 20-year life of the batteries.

In a Public Meeting held on May 27, 2010, to discuss the AP1000 Chapter 8 OIs, the staff informed the applicant that its qualification test plan for the batteries is reasonable but that the applicant must capture the qualification test plan as part of its licensing basis.

In a letter dated June 18, 2010, the applicant stated that it would revise its DCD to include the battery qualification test program. The applicant included the proposed revised Section 8.3.2.1.4, “Description,” of the DCD as part of its response as follows:

> The qualification test program for AP1000 24-hour and 72-hour class 1E batteries meets or exceeds the requirements of IEEE Std 323, IEEE Std 344 and IEEE Std 535 including required and recommended margins and is in regulatory compliance with RGs 1.89, 1.100 and 1.158. The test program requires that the battery be subjected to accelerated thermal aging and discharge cycling (wear aging) in accordance with Institute of Electrical and Electronics Engineers (IEEE) Std 323 and IEEE Std 535 over its qualified life objective followed by the DBE seismic event performed in accordance with IEEE Std 344. In addition, following the aging process, the test specimens shall be subjected to environmental testing to verify the equipment’s ability to operate in postulated abnormal environmental conditions during plant operation. Discharge cycling will be performed as a potential aging mechanism prior to seismic testing using Type 3 modified performance test method in accordance with IEEE Std 450-2002 at intervals representative of the AP1000 surveillance test requirements of the batteries with 10 percent margin in the number of discharge cycles which establishes margin for the expected life of the battery. Thus, magnitude / duration (modified performance test versus service and performance tests) and test interval envelop the AP1000 and industry cycling requirements. If new battery failure modes are detected during the qualification testing, these failure modes will be evaluated for any potential changes to the technical specification’s surveillance requirements and revision to maintenance procedures required to ensure identification of degradation prior to reaching those failure modes during plant operation. Following the qualification process, a report that uniquely describes step-by-step the tests performed and results and addressing any deficiencies and repairs including photographs, drawings, and other materials will be maintained for records.

Based on the above, the staff concluded the applicant’s test plan provided in EQ-TP-59-APP (APP-DB01-VPH-001) satisfies the recommendations of IEEE Standard 323-1974, IEEE Standard 344-1987, and IEEE Standard 535-1986 and provides reasonable assurance that its batteries and racks will perform their required functions throughout their qualified life. Therefore, OI-SRP-8.3.2-EEB-04 is resolved subject to the verification that the DCD is updated to include the revised paragraph. This is CI-SRP8.3.2-EEB-04.

In RAI-SRP8.3.2-EEB-05, the NRC staff stated that in order for staff to assess the adequacy of the dc power systems, it needed the results of 250 Vdc battery and battery charger sizing calculations, battery terminal voltage calculations, short circuit calculations, and voltage drop calculations and the associated assumptions used.

In a response dated May 7, 2009, the applicant stated that the results of 250 Vdc battery and battery charger sizing calculations, battery terminal voltage calculations, short circuit calculations, and voltage drop calculations will be available during a design review stage. This was tracked as OI-SRP8.3.2-EEB-05 in the SER with OIs.

Subsequently, in a letter dated April 21, 2010, as part of the response to OI-SRP-8.3.2-EEB-05, the applicant provided document APP-IDS-EOC-001, Revision 0, “Class 1E 250 V DC Battery Sizing, Charger Sizing and Available Short Circuit Current,” for staff review at its Rockville, Maryland office. The document contains information to assess adequacy of the battery banks and chargers for use in the Class 1E dc and Uninterruptable Power Supply (UPS) for the AP1000 plant. The staff reviewed the applicant’s on-site documentation that describes applicant’s methodology for sizing batteries, chargers, and the available short circuit current from these sources. The staff verified that AP1000 Class 1E batteries are sized in accordance with the recommendations of IEEE Standard 485, and the battery chargers are sized in accordance with the recommendations of IEEE Standard 946, “IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations.” These standards provide guidance for sizing batteries and battery chargers. During its review of the document the staff noticed that the required capacity of an IDSC-DB Division C, 72-hour battery is 2430 AH, while the batteries are rated for only 2400 AH per the DCD. In a public meeting held on May 27, 2010, the staff asked the applicant to justify the apparent difference in required capacity of 72-hour battery per calculation versus the stated capacity of the 72-hour battery listed in Table 8.3.2-5 of the DCD.

In a letter dated June 18, 2010, the applicant stated that the required capacity of the IDSC-DB Division C, 72-hour battery in the APP-IDS-EOC-001, Revision 0, will be revised to be made consistent with the DCD. This change will be included in the next revision of the document due out August 2010. The staff finds applicant’s commitment to be acceptable because the revised calculations will ultimately be reviewed by the staff as part of the ITAAC for the dc system.

Based on its review, the staff concluded that applicant’s methodology for sizing batteries and battery chargers using these standards provides reasonable assurance that the batteries and battery chargers will be sized adequately and perform their safety functions as designed. The staff also verified that the dc switchboards rating exceeds the available short circuit current contributions from the batteries, battery chargers and regulating transformers. Further, Inspection Test Analysis and Acceptance Criteria (ITAAC) verifying that the batteries, chargers, and distribution systems are adequately designed are identified in DCD Tier 1, Tables 2.6.3.7, 8, 9, and 10. The NRC staff will ultimately verify these ITAAC to ensure that the dc distribution system components including the batteries and battery chargers are adequately designed and the as-built design conforms to the approved plant design and applicable regulations. Therefore, OI-SRP8.3.2-EEB-05 is resolved.

In RAI-SRP8.3.2-EEB-06, the NRC staff noted that DCD Section 8.3.2.1.1.1 for 72-hour 250 Vdc batteries states, “Each switchboard connected with a 72-hour battery bank supplies power to an inverter. No load shedding or load management program is needed to maintain power during the required 24-hour safety actuation period.” The staff requested the applicant to clarify if manual actions would be necessary to maintain power during the required 72 hours and to describe the loads that would be shed after 24 hours.

In its response dated May 7, 2009, the applicant confirmed that no operator action is necessary during the 72-hour period to maintain the adequacy of either the 24-hour or 72-hour portions of the dc power system. The above satisfies the staff’s concern and this item is resolved.

In RAI-SRP8.3.2-EEB-08, the NRC staff noted that Figure 2.6.1-1, Tier 1 of the DCD shows that the motor control centers that feed the safety-related 250 Vdc battery chargers are fed from 480 V load centers. The applicant was asked to provide a detailed drawing of the 480 V load centers, the MCC that feed the battery chargers, and the dc motor control center showing typical loads powered from these buses. The applicant was asked to describe how the 480 V load centers are protected from degraded voltage and frequency conditions and to provide the following information:

a. The results of an analysis of the onsite power distribution system to demonstrate that adequate voltages at terminals of the battery chargers are optimized for the maximum and minimum voltage variations of the offsite power for events such as a unit trip, loss-of-coolant accident, startup or shutdown.
b. A description of the analytical techniques, methodology, and assumptions used in performing the analyses. Also, provide the results of these analyses for each level of onsite electrical power distribution.
c. Identification of the analytical software (and its version) used for performing these studies and make available to the NRC staff an electronic copy of the electrical distribution system model that forms the basis of the analytical studies.

In a response dated June 23, 2009, the applicant stated that the level of design detail requested would be available following the completion of the design review stage of the system. In general, the NRC staff was seeking understanding of the applicant's approach to assuring consistency in the transfer to the Combined Operating License (COL) applicant the 1) analysis, calculations and assumptions made for maintaining adequate voltage regulation at safety-related equipment terminals, 2) the analysis and assumptions used to evaluate acceptable rating for equipment such as circuit breakers, 3) the studies, acceptance criteria, and assumptions used to determine equipment sizing. This was tracked as OI-SRP8.3.2-EEB-08 in the SER with OIs.

Subsequently, in letters dated February 1, and May 11, 2010, the applicant stated that to assure consistency in the transfer of design information to a COL applicant, it provides a COL applicant with a configuration-controlled model developed through the use of an Electrical Transient Analysis Program. The Program includes the non-safety related ac design calculations, including design inputs, assumptions, methodologies, and acceptance criteria used in the development of the sizing basis, settings, load flow, short circuit and voltage regulation. In addition, the applicant stated that it has performed an analysis of its onsite ac distribution system and that the results of the analysis of the onsite power distribution system demonstrate that adequate voltages at terminal of the battery chargers are optimized for the maximum and minimum voltage variations of the offsite power for events such as a unit trip, loss-of-coolant accident, startup or shutdown. The above will ensure that adequate voltages at terminal of the battery chargers are optimized for the maximum and minimum voltage variations of the offsite power to satisfy the requirements of General Design Criteria (GDC) 17 with respect to their capacity and capability to perform their safety function. Though the applicant did not submit this information for staff review, the staff determined this response to be acceptable because ultimately all COL applicants would have to complete testing of the onsite (ac and dc) and offsite power systems which are fully interconnected to verify that the Non-Class 1E ac power system will have an acceptable design to support the safety-related loads. Therefore, OI-SRP8.3.2-EEB-08 is resolved.

In RAI-SRP8.3.2-EEB-09, the NRC staff noted that the AP1000 is designed to sustain a load rejection from 100 percent power with the turbine generator continuing stable operation while supplying the plant house loads. The staff is concerned about the transient conditions where a significant voltage spike during islanding could cause high dc voltage conditions on the output side of the battery chargers. Operating experience (see NRC Information Notice (IN) 2006-18, "Significant Loss of Safety-Related Electrical Power at Forsmark, Unit 1, in Sweden" dated August 17, 2006) has shown that the voltage spike either due to malfunction of the main generator exciter or during islanding could go as high as 130 percent, which could go undetected by normally-provided relaying and could cause damage to the safety-related equipment or miss-operation. In this regard, the applicant was asked to describe how the protective features of the inverter and the new battery chargers would be coordinated so that any voltage transient would not result in inadvertent loss of the inverters or the batteries.

In a letter dated June 23, 2009, the applicant stated that the battery charger input circuit will conduct power to charge the batteries when ac power is available. The battery charger is specified to return to operation after voltage drifts outside of an acceptable input voltage range. The battery charger is also a qualified isolation device, isolating the battery and the inverter from the non-safety related ac system. During the period where the battery charger is not conducting, the battery will carry the load. In addition, the applicant stated that it has considered over-voltage events with the potential to have effects upon plant safety-related equipment as provided under the direction of IN 2006-18. However, the applicant did not provide the details of how to avoid this kind of event in AP1000 design or identification of potential vulnerabilities and actions that could reduce the challenges for the control room operators. This potential event is significant in that it can cause the common mode failure in all four trains and, therefore, could result in the loss of all four trains of safety-related ac and dc power. Transient voltages on the ac input to the battery chargers can result in high dc voltages that could lead to failures of critical electrical and electronic components including electrical inverters unless they are properly protected. During such a voltage transient, the inverter voltage surge protection could trip before actuation of the battery charger protection if the battery charger and inverter direct current voltage protection settings are very close to each other. Therefore, it is necessary that the safety-related battery chargers and inverter trips be coordinated such that the associated inverters do not trip on during voltage transients on the ac distribution system. This was tracked as OI-SRP8.3.2-EEB-09 in the SER with OIs.

Subsequently, in letters dated January 26, and May 11, 2010, the applicant stated that as part of the component design specification, the battery charger/inverter will be designed specifically with consideration of the Forsmark incident identified in IN 2006-18. Industry evaluations of this incident identify the lack of coordination as a primary causative issue. In addition, the applicant stated that the protective devices will be set so that the battery charger will not trip on the over-voltage resulting from load rejection and will be set low enough to protect the equipment. The inverter dc input protection will be set at least 10% higher than the battery charger output dc protection to prevent the inverter tripping before the battery charger.

In a public meeting held on May 27, 2010, to discuss AP1000 Chapter 8 OIs, the staff informed the applicant that its response to the above OI was inadequate. The staff stated that the safety-related inverter high dc input voltage trip set point and the associated battery charger high dc output voltage trip set point should be coordinated in both magnitude and time. The staff stated that the applicant should amend the DCD to include its response as modified.

In a letter dated June 18, 2010, the applicant provided a proposed revision to Section 8.3.2.1.4, “Maintenance and Testing,” of the DCD as part of its response to OI-SRP8.3.2-EEB-09 as follows:

> The inverter DC input protection will be set at least 10 percent higher than the battery charger trip setpoints to prevent the inverter tripping before the battery charger. The time delay for the inverter high dc input voltage trip will be set higher than the delay time delay for the battery charger to prevent the inverter tripping before the battery charger.

In addition, the applicant stated in its response dated May 11, 2010 that the battery charger function in AP1000 design is to provide isolation between input ac and the dc system and to provide dc power when ac power is available. The staff noted that Section 8.3.2.2 of the DCD states that Class 1E battery chargers and Class 1E voltage-regulating transformers are designed to limit the input (ac) current to an acceptable value under faulted conditions on the output side. Both have built-in circuit breakers at the input and output sides for protection and isolation. The circuit breakers are coordinated and periodically tested to verify their current-limiting characteristics. In the public meeting held on May 27, 2010, the staff requested the applicant to explain how the requirement for periodic testing of the Class 1E battery chargers and Class 1E voltage-regulating transformers used as isolation devices will be satisfied by each COL applicant. The staff requested that the applicant indicate where this requirement will be located so that periodic testing of these devices is performed by each applicant to satisfy the recommendations of IEEE Std 384, ”IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits,” endorsed by RG 1.75, “Physical Independence of Electric Systems.”

In the letter dated June 18, 2010, the applicant stated that a COL Information Item will be added to the DCD to ensure that periodic testing is performed on the battery chargers and the regulating transformers. The applicant included the proposed revised Section 8.3.3, “Combined License Information for Onsite Electric Power,” of the DCD as part of its response as follows:

> Combined License applicants referencing the AP1000 certified design will ensure that periodic testing is performed on the battery chargers and voltage regulating transformers.

Based on the above, the staff concluded that the applicant’s modified response on battery charger and inverter trip setpoints satisfies the requirements of GDC 17 with respect to the capability of dc systems to perform their safety function. The staff determined that the addition of the above COL Information Item to the DCD will ensure that periodic testing is performed on the battery chargers and the regulating transformers in accordance with the requirements of GDC 18, “Inspection and testing of electric power systems.” Therefore, OI-SRP8.3.2-EEB-09 is resolved subject to the verification that the DCD is updated to include the revised paragraphs. **This is Confirmatory Item CI-SRP8.3.2-EEB-09.**

In RAI-SRP8.3.2-EEB-10, the NRC staff remarked that Note 8 on Figure 8.3.1-4, “Inside Diesel Generator Building,” (Sheets 1 and 2) of the DCD indicates that the diesel generators include DC pre-lube oil pumps and keep-warm lube oil heaters and that these loads are not included on Tables 8.3.2-2, “250 Vdc Class 1E Division B Battery Nominal Load Requirements,” and -3, “250 Vdc Class 1E Division C Battery Nominal Load Requirements,” of the DCD. Additionally, the same tables do not include dc power requirements to close and recharge the springs of the circuit breakers, nor do they include the dc power requirements for diesel generator field flashing and starting. The staff asked the applicant to indicate whether the battery sizing will include these loads or provide a reference to where these loads are powered from.

In the response dated May 7, 2009, the applicant stated that the non-safety-related diesel generator (DG) dc loads are not powered from the safety-related batteries. The required DG dc loads will be powered from the non safety-related dc system. Non safety-related breakers will also have their spring charging motors powered from the non-safety-related dc system.

The safety-related breakers, reactor trip and RCP trip will receive their control power from the safety-related dc system. Based on the above information, the NRC staff finds this issue resolved.

8.3.2.1.1.2 Conclusion

The NRC staff has reviewed the proposed changes to the system voltage for the operation of Class 1E dc loads from 125 Vdc to 250 Vdc and concludes that the proposed changes are acceptable subject to the satisfactory resolution of the confirmatory items discussed above.

8.3.2.3 <u>Non-Class 1E dc and UPS System</u>

In this Section of the FSER, the NRC staff stated that the non-Class 1E dc and UPS system consists of the dc electric power supply and distribution equipment that provides dc and uninterruptible ac power to the plant non-Class 1E dc and ac loads that are needed for plant operation and investment protection. Direct current buses 1, 2, and 3 provide 125 Vdc power to the associated inverter units that supply the ac power to the non-Class 1E UPS system. Bus 4 supplies large dc motors and other dc power loads, but not inverter loads.

In Revision 17 to the DCD, the applicant added another dc subsystem, which includes a battery, a battery charger, and the associated dc distribution equipment, and monitoring and protection devices to serve non-safety-related loads.

The portions of the AP1000 DCD affected include pages 8.3-18 to 20, 24, Table 8.3.2-6 (Sheet 1) and new Table 8.3.2-6 (Sheet 2). The portions of the Tier 1 AP1000 DCD affected include Table 2.6.1-2 (untitled), Section 2.6.2, "Non - Class 1E dc and Uninterruptible Power Supply System," and Table 2.6.2-1, "Inspections, Tests, Analyses, and Acceptance Criteria," Table 2.6.2-2 (untitled), and Figure 2.6.2-1, "Non-Class 1E dc and Uninterruptable Power Supply System" (Sheet 2 of 2).

8.3.2.3.1 Evaluation

The applicant added an additional dc Subsystem (EDS5) in the Non-Class 1E portion of the dc and UPS System in the AP1000 design which includes a battery, a battery charger, and the associated dc distribution equipment, and monitoring and protection devices. As a result of the addition of the non-Class 1E dc Subsystem EDS5, the large dc motors that were originally powered from EDS4 will now be powered from new EDS5.

8.3.2.3.2 Conclusion

The NRC staff has reviewed the proposed change and concludes that the addition of Subsystem EDS5 provides greater flexibility to service the Non-Class 1E portion of the dc and UPS system for the AP1000 design. Since the proposed change has no impact on the safety-related systems, the proposed change is acceptable.

8.4 Other Electrical Features and Requirements for Safety

8.4.1 Containment Electrical Penetrations

In the first paragraph of Section 8.4.1 of the FSER, the NRC staff stated that for modular type penetrations (three penetration modules in one nozzle), the applicant has assigned the following:

- one module for low-voltage power
- one module for 120 Vac/125 volts direct current control and signal
- one module for instrumentation signal

In TR-79, the applicant deleted the above assigned module separation criteria for cables of varying voltage service levels. In addition, the applicant revised Figure 8.3.1-1 of the DCD to correct penetration numbers associated with each RCP.

As a result of the above changes to Tier 2, the portions of the Tier 1 AP1000 DCD affected include Figures 2.6.1-1 (Sheet 1 of 4) and 2.6.1-1 (Sheet 3 of 4).

In addition, in Tier 1, Section 2.2.1, "Containment System," and Table 2.2.1-3, "Inspections, Tests, Analysis, and Acceptance Criteria," the applicant added a new item "6d" to address environmental qualification requirements for non-Class 1E electrical penetrations to resolve the NRC staff's concern in RAI-TR93-ICE2-03.

8.4.1.1 Evaluation

The applicant stated that the electrical penetration conductor modules are in penetrations of the same service class. Modules for instrumentation signals will be in instrumentation penetrations; modules for power (e.g., 120/125 V) will be in control penetrations; and modules for low-voltage power will be in low-voltage power penetrations.

In addition to the above, the applicant stated that the penetration numbers shown in Figure 8.3.1-1 of Revision 15 of the DCD were incorrect and were revised to reflect the correct penetrations associated with each RCP. The penetration numbers currently shown on the figure are E9, E10, E25, and E26. The correct penetration numbers are P10, P26, P9, and P25 for each of RCP 1B, 2B, 1A, and 2A, respectively.

With regard to qualification requirements for non-Class 1E electrical penetrations, in RAI-TR93-ICE2-03, the NRC staff expressed its concern that non-Class 1E penetrations were not qualified for a harsh environment as were Class 1E penetrations. In its response, the applicant agreed with the NRC staff that Class 1E and non-Class 1E penetrations must be qualified for maintaining their containment integrity to satisfy the requirements of General Design Criterion (GDC) 50, "Containment Design Basis," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50).

8.4.1.2 Conclusion

The NRC staff has reviewed these changes and concludes that the electrical penetration conductor modules are in penetrations of the same service class. This is consistent with the recommendations of RG 1.75, "Physical Independence of Electric Systems," and is acceptable.

The NRC staff also concludes that including environmental qualification requirements for non-Class 1E electrical penetrations satisfies the requirements of GDC 50 and is acceptable. In addition, the staff finds the proposed change to revise the penetration numbers associated with each RCP to be administrative in nature and acceptable.

8.4.2 Reactor Coolant Pump Breakers

In the first paragraph of Section 8.4.2 of the FSER, the NRC staff stated that the RCPs are powered from the four switchgear buses located in the turbine building. Each bus powers one RCP. Variable speed drives are provided for RCP startup. Two Class 1E circuit breakers connected in series power each RCP. These are the only Class 1E circuit breakers used in the main ac power system for the specific purpose of satisfying the safety-related tripping requirements of these pumps.

In TR-79, the applicant proposed to add input and output isolation breakers to each RCP variable frequency drive (VFD) unit. The proposed change would affect DCD Tier 2, Table 8.3.1-3 and Page 8.3-53 (Untitled Electrical Drawing).

As a result of the above changes to Tier 2, the portions of the Tier 1 AP1000 DCD affected include Figure 2.6-1 (Sheet 1 of 4) and (Sheet 3 of 4).

8.4.2.1 <u>Evaluation</u>

The applicant proposed to add input and output isolation breakers to each RCP VFD unit. The applicant stated that the addition of the input and output breakers allows for the VFD unit to be completely removed from service during normal plant operation by using the bypass breaker. Without the addition of these isolation breakers, the RCP pump would need to be offline in order to service the VFD unit.

There are no regulatory requirements concerning the ability to remove VFD units during normal plant operation.

8.4.2.2 <u>Conclusion</u>

The NRC staff has reviewed this change and concludes that the addition of the input and output breakers will provide the applicant flexibility to service the VFD unit without removing the RCP offline and that this change has no impact on the safety systems. Therefore, the proposed change is acceptable.